Sunshine State Standards

SC.C.2.3.7: The student knows that gravity is a universal force that every mass exerts on every other mass.

SC.H.1.3.1: The student knows that scientific knowledge is subject to modifications as new information challenges prevailing theories and as a new theory leads to looking at old observations in a new way.

Vocabulary

- Satellite p. 687
- Space station p. 688
- Lander p. 692
- Probe p. 693

Before, you learned

- The motions of planets and other nearby objects are visible from Earth
- Light and other forms of radiation carry information about the universe

Now, you will learn

- How astronauts explore space near Earth
- How different types of spacecraft are used in exploration

EXPLORE Viewing Space Objects

How do objects appear at different distances?

Procedure

1. Crumple the paper into a ball and place it on your desk.

2. Sketch the ball at the same time as another student sketches it. One of you should sketch it from a distance of 1 m. The other should sketch it from 5 m away.

What do you think?

- How do the details in the two drawings compare?
- What details might be easier to see on a planet if you were orbiting the planet?

Astronauts explore space near Earth.

Space travel requires very careful planning. Astronauts take everything necessary for survival with them, including air, water, and food. Spacecraft need powerful rockets and huge fuel tanks to lift all their weight upward against Earth’s gravity. The equipment must be well designed and maintained, since any breakdown can be deadly.

Once in space, astronauts must get used to a special environment. People and objects in an orbiting spacecraft seem to float freely unless they are fastened down. This weightless condition occurs because they are falling in space at the same rate as the spacecraft. In addition, to leave their airtight cabin, astronauts must wear special protective suits. Despite these conditions, astronauts have managed to perform experiments and make important observations about space near Earth.
Moon Missions

For about a decade, much of space exploration was focused on a race to the Moon. This race was driven by rivalry between the United States and the Soviet Union, which included Russia. In 1957 the Soviet Union launched the first artificial satellite to orbit Earth. A satellite is an object that orbits a more massive object. The Soviet Union also sent the first human into space in 1961. Although the United States lagged behind in these early efforts, it succeeded in sending the first humans to the Moon.

**Preparation** Many steps had to be taken before astronauts from the United States could visit the Moon. The National Aeronautics and Space Administration (NASA) sent spacecraft without crews to the Moon to find out whether it was possible to land on its surface. NASA also sent astronauts into space to practice important procedures.

**Landings** The NASA program to reach the Moon was called Apollo. During early Apollo missions, astronauts tested spacecraft and flew them into orbit around the Moon. On July 20, 1969, crew members from Apollo 11 became the first humans to walk on the Moon’s surface. NASA achieved five more Moon landings between 1969 and 1972. During this period, the Soviet Union sent spacecraft without crews to get samples of the Moon’s surface.

**Scientific Results** The Apollo program helped scientists learn about the Moon's surface and interior. Much of the information came from 380 kilograms (weighing 840 lb) of rock and soil that astronauts brought back to Earth. These samples are still being studied.
Orbiting Earth

A **space station** is a satellite in which people can live and work for long periods. The United States and the Soviet Union launched the first space stations in the early 1970s. After the breakup of the Soviet Union in 1991, the Russian space agency and NASA began to act as partners rather than rivals. Russian and U. S. astronauts carried out joint missions aboard **Mir** (meer), the Russian space station.

The Mir missions helped prepare for the International Space Station (ISS). The United States, Russia, and 15 other nations are working together to build the ISS. When completed, it will cover an area about as large as two football fields. The ISS is too large to launch into space in one piece. Instead, sections of the space station are being launched separately and assembled in orbit over a period of years.

Construction of the ISS began in 1998. The first three-member crew arrived at the station in 2000. In addition to constructing the station, crew members make observations of Earth and perform experiments. Some experiments are much more effective when they are performed in space, where gravity affects them differently. For example, scientists can grow cell tissue more easily in space than they can on Earth. Research on cell tissue grown in space may increase our understanding of cancer and other diseases.

**International Space Station**

Each section of the space station has a specific function.

- **robot arm for assembling new sections**
- **air-lock exit for space walks**
- **main science facility**
- **storage**
- **living quarters**
- **shuttle dock**
- **solar panels to provide energy**
Research and technological advances from the space station may lay the groundwork for new space exploration. ISS crew members study how living in space affects the human body over long periods. This research may provide useful information for future efforts to send astronauts to other planets.

Most crews have flown to the ISS aboard space shuttles. Unlike earlier spacecraft, a space shuttle can be used again and again. At the end of a mission, it reenters Earth’s atmosphere and glides down to a runway. The large cargo bay of a space shuttle can carry satellites, equipment, and laboratories.

NASA has launched space shuttles more than 100 times since 1981. Space shuttles are much more sophisticated than the Apollo spacecraft that carried astronauts to the Moon. However, space travel remains a dangerous activity.

Why might some researchers choose to perform experiments aboard a space station rather than on Earth?

How does Earth’s rotation affect launches of spacecraft?

**PROCEDURE**

1. Tightly wad 14 sheets of paper into balls, and place the balls in a small bucket.
2. Stand 1.5 m away from a large bucket placed on a desk. Try tossing 7 balls into the bucket.
3. While turning slowly, try tossing the remaining 7 balls into the bucket.

**WHAT DO YOU THINK?**

- How much more difficult was it to toss the paper balls into the bucket while you were turning than when you were standing still?
- Why does Earth’s rotation make launching rockets into space more complicated?

**CHALLENGE** How would you design an experiment to show the variables involved in a launch from Earth toward another rotating body in space, such as the Moon?
Spacecraft carry instruments to other worlds.

Currently, we cannot send humans to other planets. One obstacle is that such a trip would take years. A spacecraft would need to carry enough air, water, and other supplies needed for survival on the long journey. Another obstacle is the harsh conditions on other planets, such as extreme heat and cold. Some planets do not even have surfaces to land on.

Because of these obstacles, most research in space is accomplished through the use of spacecraft without crews aboard. These missions pose no risk to human life and are less expensive than missions involving astronauts. The spacecraft carry instruments that test the compositions and characteristics of planets. Data and images are sent back to Earth as radio signals. Onboard computers and radio signals from Earth guide the spacecraft.

Spacecraft have visited all the major planets in our solar system except Pluto. NASA has also sent spacecraft to other bodies in space, such as comets and moons. Scientists and engineers have designed different types of spacecraft to carry out these missions.

Flybys

The first stage in space exploration is to send out a spacecraft that passes one or more planets or other bodies in space without orbiting them. Such missions are called flybys. After a flyby spacecraft leaves Earth’s orbit, controllers on Earth can use the spacecraft’s small rockets to adjust its direction. Flyby missions may last for decades. However, because a spacecraft flies by planets quickly, it can collect data and images from a particular planet only for a brief period.

As a flyby spacecraft passes a planet, the planet’s gravity can be used to change the spacecraft’s speed or direction. During the flyby of the planet, the spacecraft can gain enough energy to propel it to another planet more quickly. This method allowed Voyager 2 to fly past Saturn, Uranus, and Neptune, even though the spacecraft left Earth with only enough energy to reach Jupiter.

Many complex mathematical calculations are needed for a flyby mission to be successful. Experts must take into account Earth’s rotation and the positions of the planets that the spacecraft will pass. The period of time when a spacecraft can be launched is called a launch window.
Orbiters

The second stage in space exploration is to study a planet over a long period of time. Spacecraft designed to accomplish this task are called orbiters. As an orbiter approaches its target planet, rocket engines are fired to slow the spacecraft down. The spacecraft then goes into orbit around the planet.

In an orbiter mission, a spacecraft orbits a planet for several months to several years. Since an orbiter remains near a planet for a much longer period of time than a flyby spacecraft, it can view most or all of the planet’s surface. An orbiter can also keep track of changes that occur over time, such as changes in weather and volcanic activity.

Orbiters allow astronomers to create detailed maps of planets. Most orbiters have cameras to photograph planet surfaces. Orbiters may also carry other instruments, such as a device for determining the altitudes of surface features or one for measuring temperatures in different regions.

Some orbiters are designed to explore moons or other bodies in space instead of planets. It is also possible to send a spacecraft to orbit a planet and later move it into orbit around one of the planet’s moons.

**CHECK YOUR READING** What is the main difference between a flyby spacecraft and an orbiter?

**How an Orbiter Provides Data**

Data from an orbiter are sent to Earth in the form of radio waves.

1. **Instruments on the orbiter map a planet’s surface and collect data.**
2. **The orbiter sends images and data to Earth in the form of radio waves.**
3. **Scientists use computers to analyze the images and data.**

Reminder

Remember that objects orbit, or move around, other objects in space because of the influence of gravity.
Landers and Probes

The third stage in space exploration is to land instruments on a planet or to send instruments through its atmosphere. Such a mission can tell us more about the features and properties of a planet. It can also provide clues to what the planet was like in the past.

A **lander** is a craft designed to land on a planet’s surface. After a lander touches down, controllers on Earth can send it commands to collect data. Landers have been placed successfully on the Moon, Venus, and Mars. Some have operated for months or years at a time.

The images taken by a lander are more detailed than those taken by an orbiter. In addition to providing close-up views of a planet’s surface, a lander can measure properties of the planet’s atmosphere and surface. A lander may have a mechanical arm for gathering soil and rock samples. It may also contain a small vehicle called a rover, which can explore beyond the landing site.

**Landing Sequence**

Parachutes and air bags can be used to slow a lander as it descends to a planet’s surface.

1. The spacecraft slows down as it moves through the atmosphere.
2. A parachute opens, and the lander is lowered from the spacecraft. Air bags are inflated shortly before landing.
3. The lander bounces on the surface and rolls to a stop.
4. The air bags are deflated and pulled back.
5. A rover from the lander begins to move across the surface.
One of the most successful space missions was that of *Mars Pathfinder*, which landed on Mars in 1997. *Mars Pathfinder* and its rover sent back thousands of photographs. These images provided evidence that water once flowed over the surface of Mars. Unfortunately, another lander, sent two years later, failed to work after it reached Mars.

Some spacecraft are designed to work only for a short time before they are destroyed by conditions on a planet. The term **probe** is often used to describe a spacecraft that drops into a planet’s atmosphere. As the probe travels through the atmosphere, its instruments identify gases and measure properties such as pressure and temperature. Probes are especially important for exploring the deep atmospheres of giant planets, such as Jupiter.

**Combining Missions**

A lander or a probe can work in combination with an orbiter. For example, in 1995 the orbiter *Galileo* released a probe into Jupiter’s atmosphere as it began orbiting the planet. The probe sent data back to the orbiter for nearly an hour before it was destroyed. The orbiter passed the data on to Earth. *Galileo* continued to orbit Jupiter for eight years.

Future space missions may involve even more complex combinations of spacecraft. Planners hope to send groups of landers to collect soil and rock samples from the surface of Mars. A rocket will carry these samples to an orbiter. The orbiter will then bring the samples to Earth for study.

**19.3 Review**

**KEY CONCEPTS**

1. Why are space stations important for scientific research?
2. How is information sent between Earth and a spacecraft?
3. What are the three main stages in exploring a planet?

**CRITICAL THINKING**

4. **Analyze** Why is most space exploration accomplished with spacecraft that do not have astronauts on board?
5. **Infer** Why is it important to map a planet’s surface before planning a lander mission?

**CHALLENGE**

6. **Predict** Early space exploration was influenced by political events, such as the rivalry between the United States and the Soviet Union. What circumstances on Earth might interfere with future space missions?